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MICROCLIMATES ASSOCIATED WITH *CRYPTOTERMES BREVIS* (ISOPTERA: KALOTERMITIDAE) IN THE URBAN ENVIRONMENT

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Abstract.—Thirty-day studies of structural lumber infested by *Cryptotermes brevis* revealed that microclimates in Hawaii were fairly uniform with an overall mean wood-core temperature of 24.33° C. The highest wood-core temperature was 43.31° C and the lowest was 13.94° C. The mean maximum wood core temperature across all sites was 37.04° C. Temperatures varied widely over a 24 h period with the greatest diurnal variation being 23.72° C. Thermal gradients between upper and lower locations of infestations were as high as 8.71° C. Ambient relative humidity was more variable than temperature with values varying as much as 55% RH during a single month. Monthly mean RH was as high as 75.09% and ranged from 98.2% to 27.2%.

Key Words.—Insecta, West Indian drywood termite, temperature, climate.

Climate studies on termites have been conducted with the Kalotermitidae (Rust et al. 1979, Williams 1977, Williams 1976) as well as higher termites (Jones & Nutting 1989, Greaves 1964). Rust et al. (1979) recorded climatic extremes in the desert habitats of *Incisitermes minor* (Hagen) and *Incisitermes fruticavus* Rust, and found that daytime temperatures in the desert shrub habitat of these two species routinely reached lethal levels, often exceeding 60° C in exposed soil. Drywood termite colonies were present in living shrubs, where temperatures were considerably lower than those of the surrounding soil, and extended from the coolest basal portions into the peripheral branches where temperatures were much higher. Additionally, Williams (1976) reported the stress limits for *Cryptotermes brevis* (Walker), and Williams (1977) found similarities between observed macroclimatic values and physiological limits established in the laboratory. To date however, no published works have documented the microclimate, i.e., the climate existing within the microhabitat (gallery systems), of *C. brevis*.

Insects live in dynamic environments (Geiger 1965) and have various adaptations for dealing with environmental extremes. Recent work with *Hodotermes mossambicus* (Hagen) established that termites living in warmer habitats have higher thermotolerances than those from cooler habitats (Mitchell et al. 1993). Microclimatic extremes are of particular interest with *C. brevis* because high temperatures are currently being used to control this termite species (Woodrow & Grace 1997).

Hawaii represents an ideal setting to study *C. brevis* biology because it is a common pest throughout the islands. In addition, the climate is relatively constant throughout the year. In Honolulu, mean temperatures during the warmest and coolest months vary, on average, less than 4° C while diurnal variation can be on the order of 5 to 10°; varying more within a typical day than throughout the entire year (Armstrong 1983). Thus, in contrast with more variable North American conditions, a small time period can be representative of the climate. In the present study, thirty-day observations were taken of temperature fluctuations in the warmest and coolest portions of infested lumber along with ambient temperature and relative humidity within residential and commercial structures on the island of Oahu, Hawaii.

Materials and Methods

Four study sites were selected on the basis of accessibility. A thorough visual inspection was performed to determine the location and extent of *C. brevis* infestations prior to placing thermocouples. Thermocouples were placed in the potentially hottest (highest point facing clear sun in the case of an attic infestation), or the coolest (lowest) locations within a given infested board. Two 1.1 mm (7/64 in) dia holes were drilled to the center of the infested lumber, one at the highest and one at the lowest possible sites. Temperatures within the drilled cores were recorded with Hobo XT temperature loggers (Onset Computer Corp., Pocasset, Massachusetts) (accuracy: ± 0.75° C), which were pre-equipped with thermistor probes which were inserted into the cores. Ambient relative humidity was recorded with a Hobo-RH (Onset Computer Corp., Pocasset, Massachusetts) (accuracy: ± 5%) and ambient temperature with a Hobo-Temp (Onset Computer Corp., Pocasset, Massachusetts) (accuracy: ± 0.5° C) at the highest possible site on a given board. Data loggers were set to record temperature every 24 minutes for a period of 30 days.

Microclimate surveys took place within four non-air-conditioned structures on the island of Oahu: a warehouse at Wheeler Army Air Field, Mililani, Hawaii (7 Mar–6 Apr 1996), two single family dwellings, one at Ulua St. (19 Jan–22 Feb 1996) and one at Aina Koa St. (28 Feb–31 Mar 1997), Honolulu, Hawaii, and a warehouse on the Pearl Harbor Naval Base (14 Apr–9 May 1997). Sampling periods are purely arbitrary and based on when the infestations were reported by cooperating pest control professionals, and subsequently, when permission to do research was granted by the property owners. In the case of both residences, the readings were taken in roof-rafters; within an attic crawlspace at Ulua St. residence and in an exposed eve over the entrance to the house at the Aina Koa St. The Wheeler AAF warehouse measurements were taken in a wall stud, while the Pearl Harbor warehouse readings were taken within a hardwood shipping-pallet.

Results

Thirty-day studies of the *C. brevis* microclimates revealed that habitats in Hawaii were fairly uniform with an overall mean wood-core temperature of 24.33° C (SD = 1.36) (Table 1). The highest wood-core temperature recorded across all sensors was 43.31° C in the Ulua Street residence, and the lowest wood-core temperature, 13.94° C, was recorded in the Wheeler AAF warehouse. The mean maximum wood core temperature across all sites was 37.04° C (SD = 4.47, $n = 4$).

Ambient relative humidity was more variable than temperature with values deviating as much as 55% RH during a single month (Table 2). Monthly means ranged from 56.76% for the Ulua St. residence to 75.09% at the Aina Koa St.

Table 1. Summary temperatures (° C) from four sites on the Island of Oahu.

Location	Ht.[a] (m)	C/A[b]	Dimen.[c] (cm)	Mean ± SEM[d]	Min.	Max.
Pearl Harbor	1.2	C	pallet	25.38 ± 0.09	18.84	35.95
Aina Koa St.	3	C	3.8 × 8.6	24.76 ± 0.08	16.74	34.39
Aina Koa St.	2	C	3.8 × 8.6	24.38 ± 0.10	20.79	31.96
Ulua St.	4	C	3.8 × 8.6	25.91 ± 0.14	16.96	43.31
Ulua St.	3	C	3.8 × 8.6	24.94 ± 0.12	16.74	39.59
Ulua St.	4	A	—	26.45 ± 0.13	17.51	41.77
Wheeler AAF	0.1	C	3.8 × 13.3	22.38 ± 0.09	14.99	30.98
Wheeler AAF	5	C	3.8 × 13.3	22.56 ± 0.10	14.5	32.72
Wheeler AAF	5	A	—	21.57 ± 0.08	13.94	29.87

[a] Height above grade.
[b] Core/Ambient temperature probes.
[c] Dimensions of lumber.
[d] Thirty day mean, SEM = standard error of the mean.
— No data collected.

residence, and monthly maximums and minimums ranged from 98.2% to 79.2% and 43.3% to 27.2%, respectively.

Diurnal temperature variation was measured by determining the maximum and minimum temperatures for each day. Temperatures varied widely over a 24-h period (Table 3). The greatest amount of diurnal variation occurred at the Ulua St. residence, which had a mean difference of 14.70° C and a specific difference as high as 23.72° C. Figure 1 illustrates a typical day in a *C. brevis* microhabitat. In almost all cases, the lowest temperatures of all the probes occurred in the early morning, with temperatures slowly rising, peaking in the late afternoon and then gradually decreasing through the night. Typically, the upper core temperature rose first, followed by either the ambient or lower core locations, which tended to trail behind the upper core probe. Thermal gradients between upper and lower sites ranged from a monthly maximum of 8.71° C, 5.60° C and 4.48° C for the Aina Koa St., Wheeler AAF and Ulua St. sites, respectively.

Discussion

The similarity of wood-core temperatures across all sites could be an indication that these sites represent typical conditions for this species, at least in Hawaii. The mean (37.04° C) and absolute maximum wood core temperature (43.31° C) reported here are similar to the macroclimatic values reported previously by Williams (1977) for *C. brevis* and other *Cryptotermes* species. Williams (1977) re-

Table 2. Summary relative humidity (%) data from one month recordings at three sites on the island of Oahu.

Location	Mean ± SEM[a]	Minimum	Maximum
Wheeler AAF	63.54 ± 0.27	39.90	87.20
Ulua St.	56.76 ± 0.30	27.20	79.20
Aina Koa St.	75.09 ± 0.31	43.30	98.20

[a] Standard error of the mean.

Table 3. Wood core diurnal variation (° C) of four sites on the Island of Oahu.

Location	Mean ± SEM[a]	Maximum	Minimum
Wheeler AAF lower core	8.83 ± 0.45	13.44	4.22
Wheeler AAF upper core	10.69 ± 0.51	15.30	3.13
Ulua St. upper core	14.70 ± 0.95	23.72	3.55
Ulua St. lower core	12.49 ± 0.77	19.87	3.19
Aina Koa St. upper core	8.13 ± 0.46	13.91	1.75
Pearl Harbor NB pallet core	10.45 ± 0.44	15.02	2.79

[a] Standard error of the mean.

ported an absolute maximum of 46° C and a mean high temperature of 38° C for this species. Although *C. brevis* can tolerate short exposures to temperatures in excess of 43° (Woodrow and Grace 1998) extended exposures to 43° C are potentially lethal to this species (Scheffrahn et al. 1997, Williams 1976) and to the protozoan symbionts (Williams 1977).

In studies with termites in forest and desert habitats it has been reported that both mound building and tree inhabiting species live in a media that insulate the colony against high ambient temperatures during hot summer months (Greaves 1964, Rust et al. 1979). In a drywood termite shrub habitat, Rust et al. (1979) found that wood temperature lagged behind that of the air. Our observations indicate that the opposite occurs within structures in the urban environment. This phenomenon is most likely due to radiant heat from the sun heating up the roof which then in turn conducts the heat to the underlying wood structure, which then conducts the heat to the surrounding air (Fig. 1). Thus, living shrubs act as insulators to high ambient air temperatures, whereas in the urban environment, wood within structures may actually be more a conductor of stressful temperatures than an insulator in some cases.

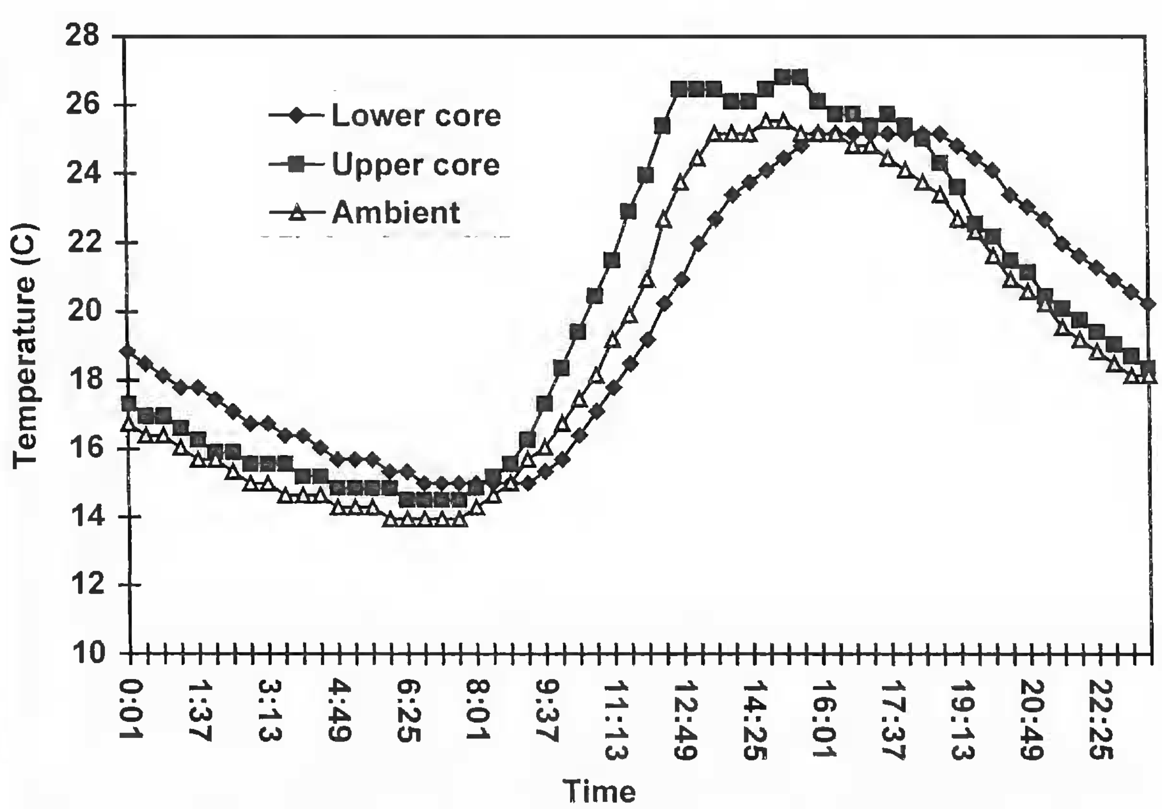

Figure 1. Twenty-four hour temperature (° C) profile of ambient and wood core temperatures of a 3.8 × 13.3 cm wall stud in a warehouse at Wheeler Army Air Field.

Although higher termites regulate their colony temperatures (Greaves 1964), drywood termites may move within their gallery systems according to where temperatures are most optimal (Rust et al. 1979, Cabrera and Rust 1996). The most extreme temperature measured in this study, 43.1° C, as discussed previously, has been shown to be potentially lethal. Thus, our results suggest that *C. brevis* might have either behavioral or physiological mechanisms for dealing with microclimatic extremes that could have implications on the use of extreme temperatures for the control of this termite species.

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